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MYRRHA

The MYRRHA/XT-ADS project : nuclear physics challenges and opportunities

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SCK•CEN,

on behalf of the MYRRHA Team

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Summary

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- Introduction
- Partitioning and transmutation
- Accelerator driven system
- MYRRHA components
- Deployment
- Nuclear Physics opportunities

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Energy problem

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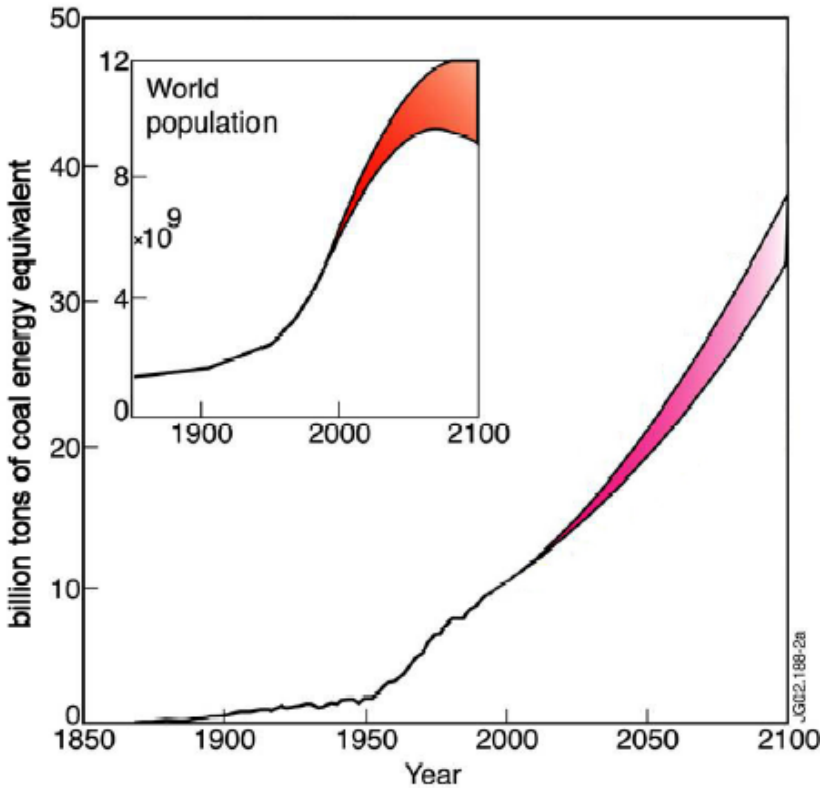

Even is everything stays the same, we get a doubling in the next 50 years

- Reduce consumption
  - Zero growth; developing nations ?
- Renewable energy ?
  - 10-15% max in our region
- Fosile fuels ?
  - Finitude, $C0_2$
- Nuclear Fusion ?
  - Great, but when ? (@ t+50y, ∀t ?)
- Nuclear Fission ?
  - Safety ?
  - Waste ?

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Waste from fission

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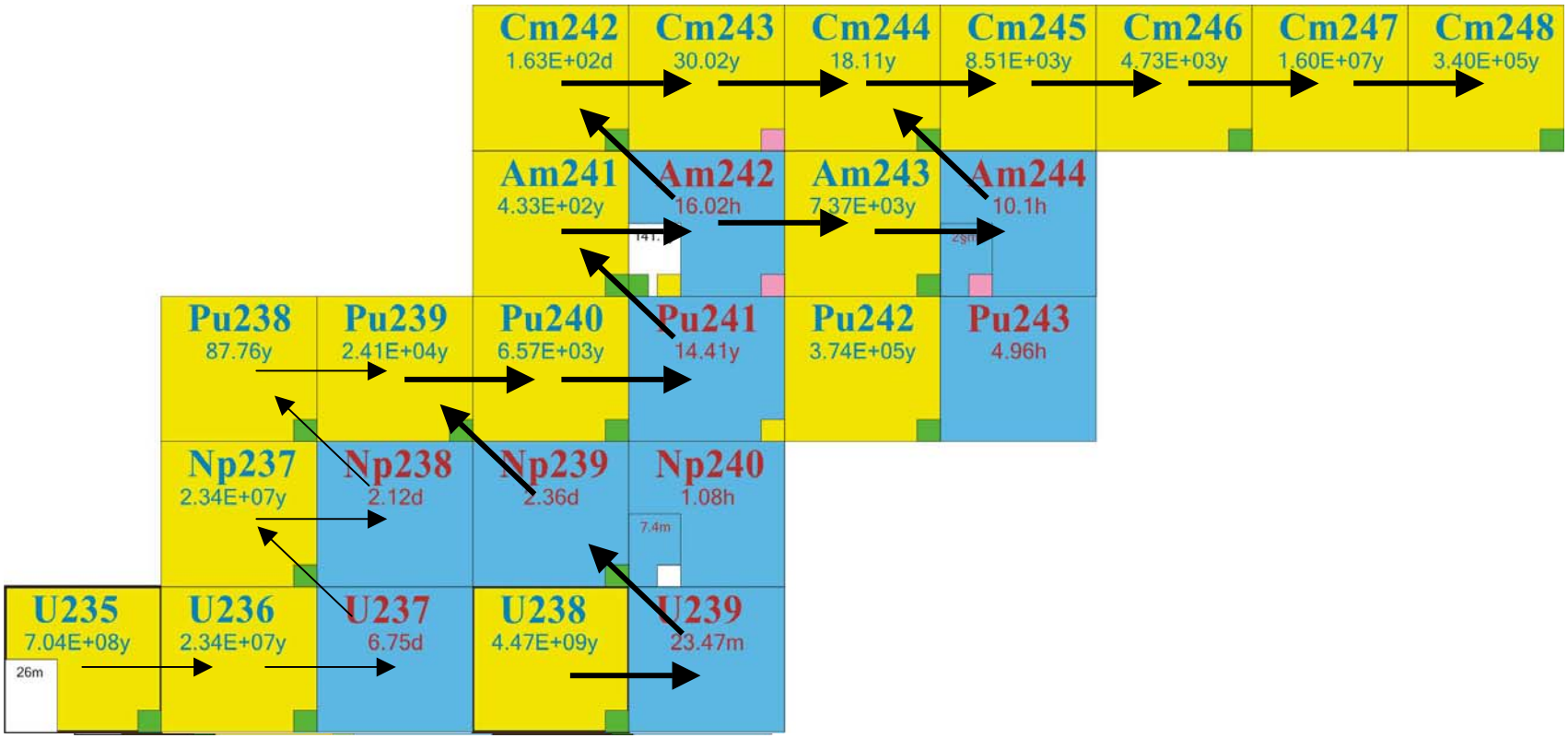

Solution : burn them

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Nuclear Energy & waste

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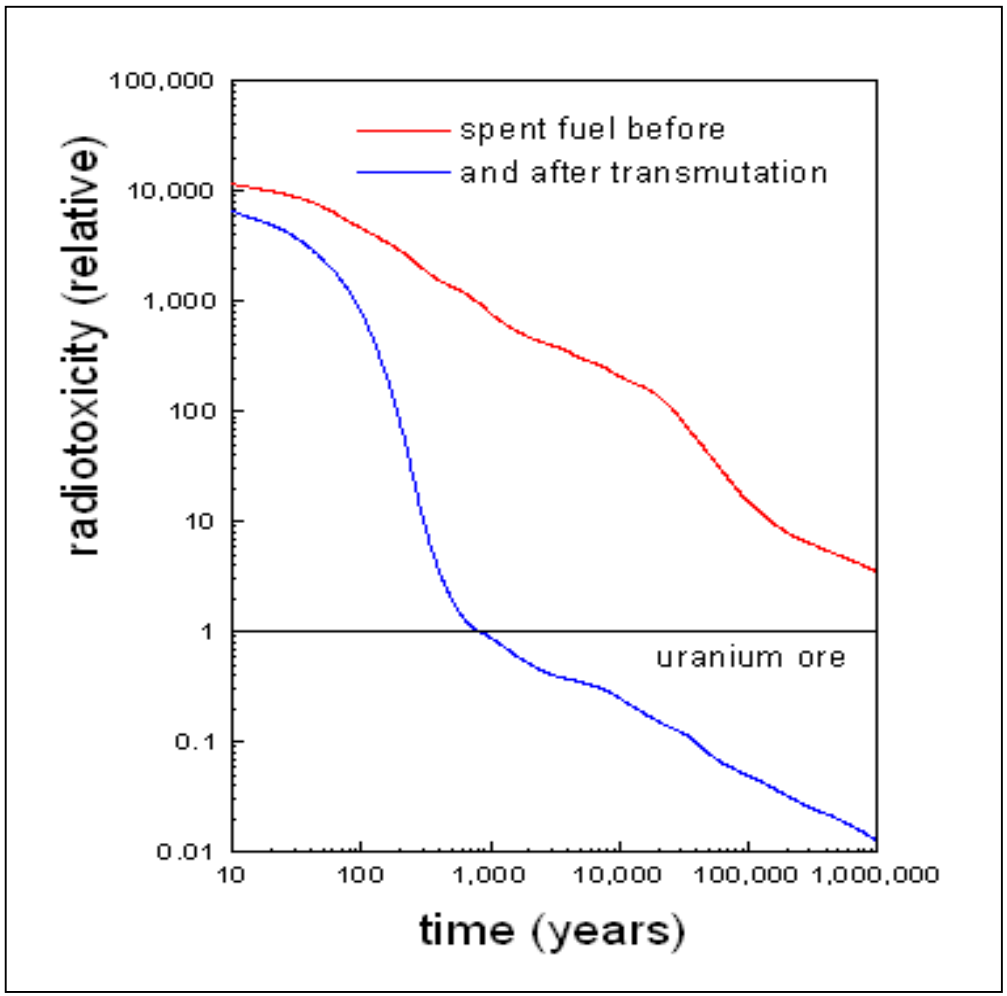

- Europe : 35% of electricity from nuclear energy
- This produces about 2500 t/y of spent fuel:
- A technical, social and environmental satisfactory solution is needed for the waste problem.
- Partitioning & Transmutation (P&T) of MA and LLFP can lead to this acceptable solution by reducing time scales for waste storage.

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Transmutation

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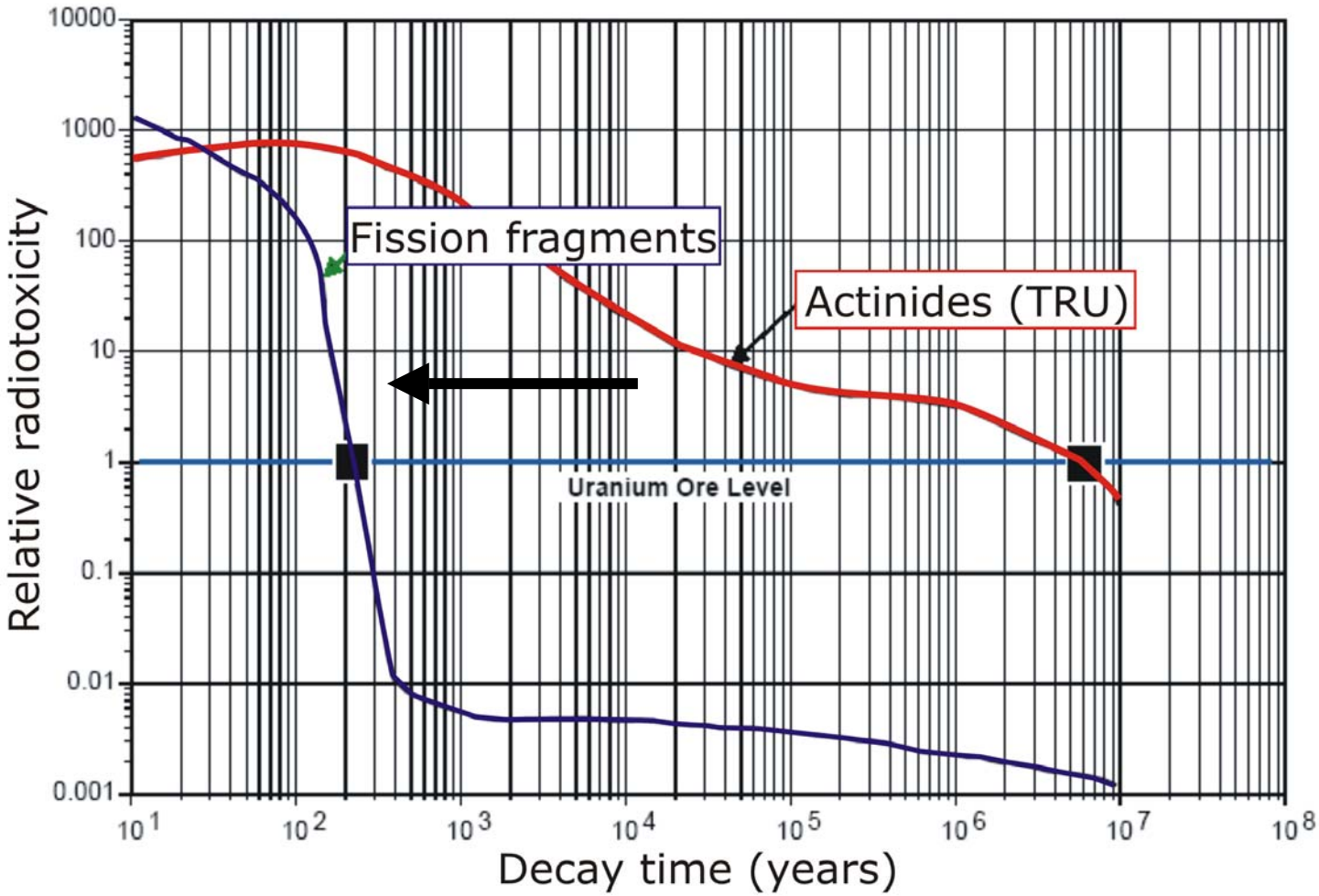

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Fission of minor actinides

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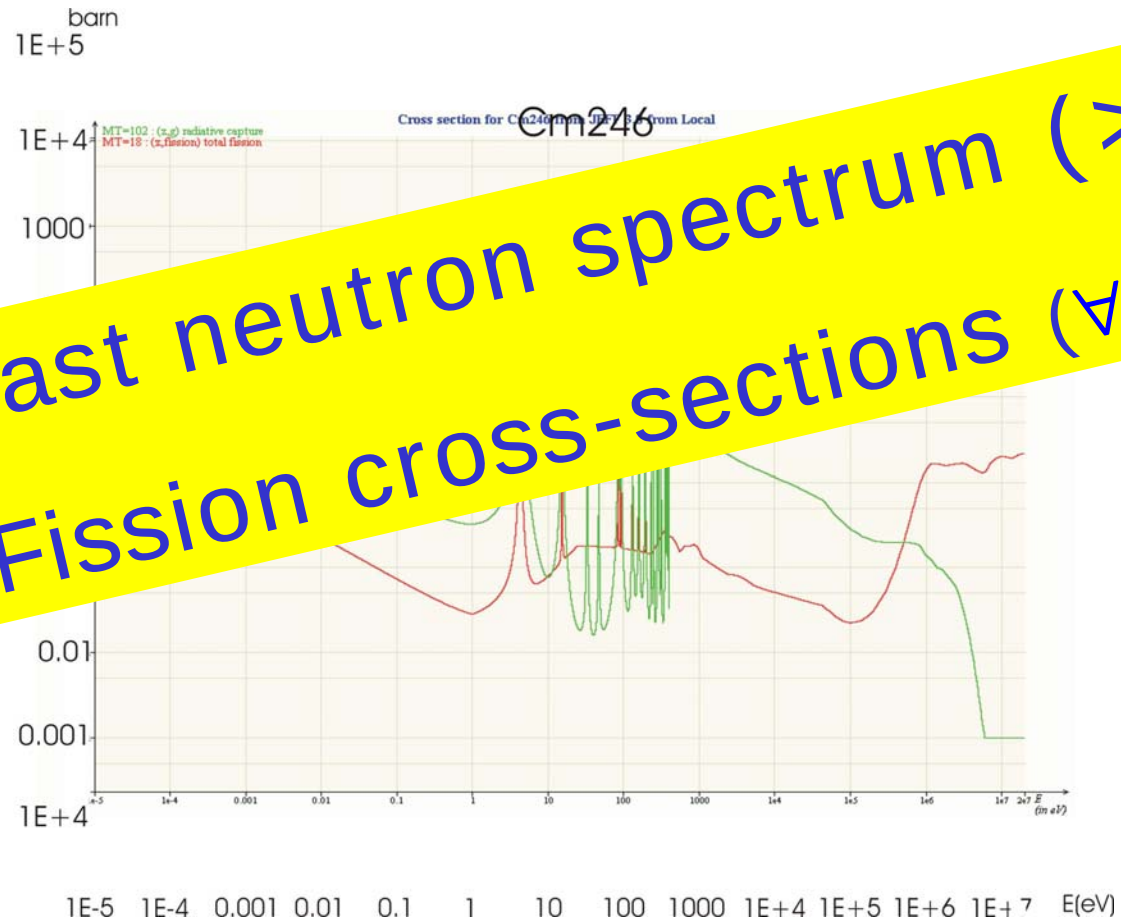
- Fast neutron spectrum (> 1MeV)
- Fission cross-sections (∀ Energies)



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Reactordynamics

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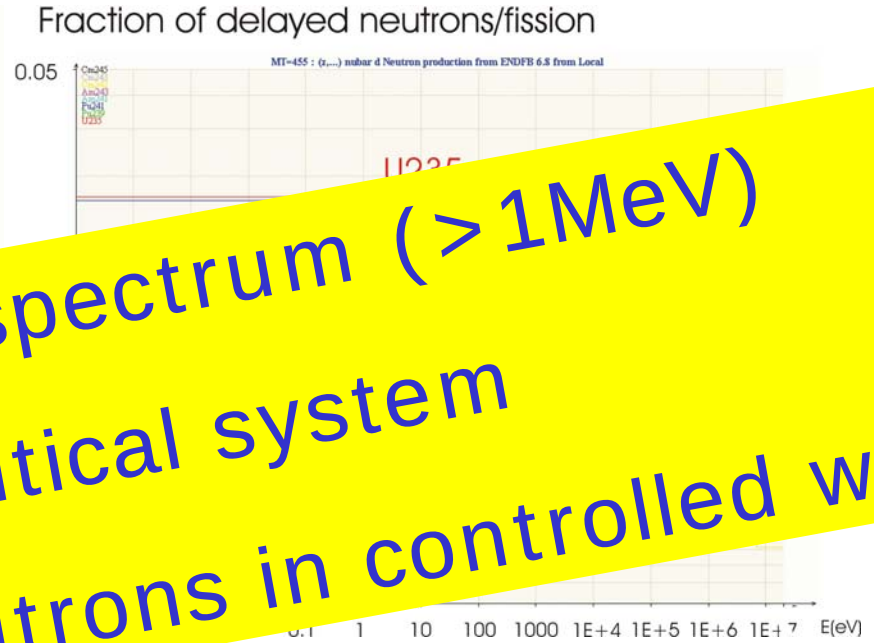


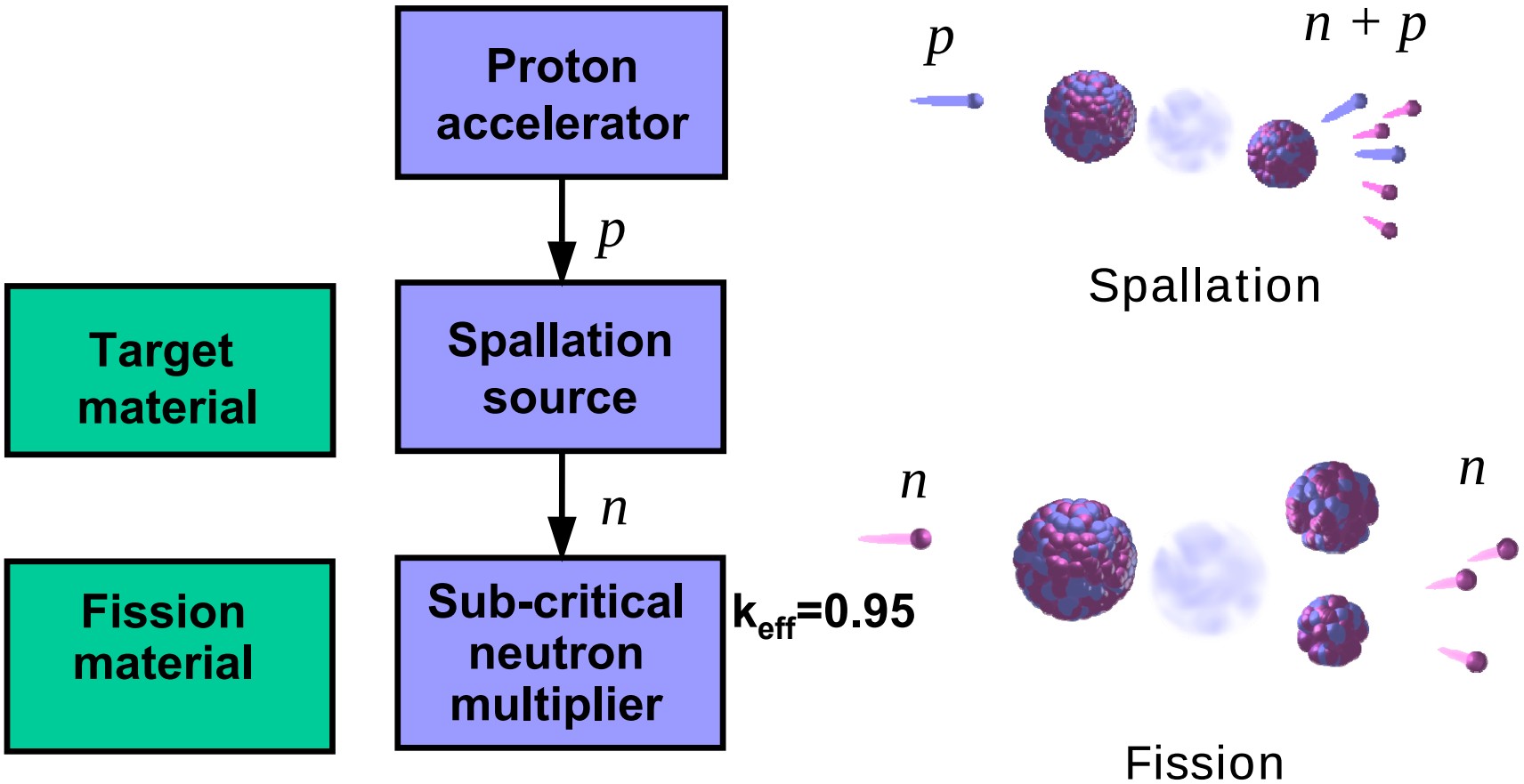
Fast neutron spectrum (>1MeV)

Sub-critical system

Feed lacking neutrons in controlled way

- T… … fission ↑: Fraction of delayed n° ↓
- MA fuel makes reactor more difficult to handle (nervous)
- Maximum MA fuel load in critical fast reactor : 1-1.5%

Accelerator driven system Concept



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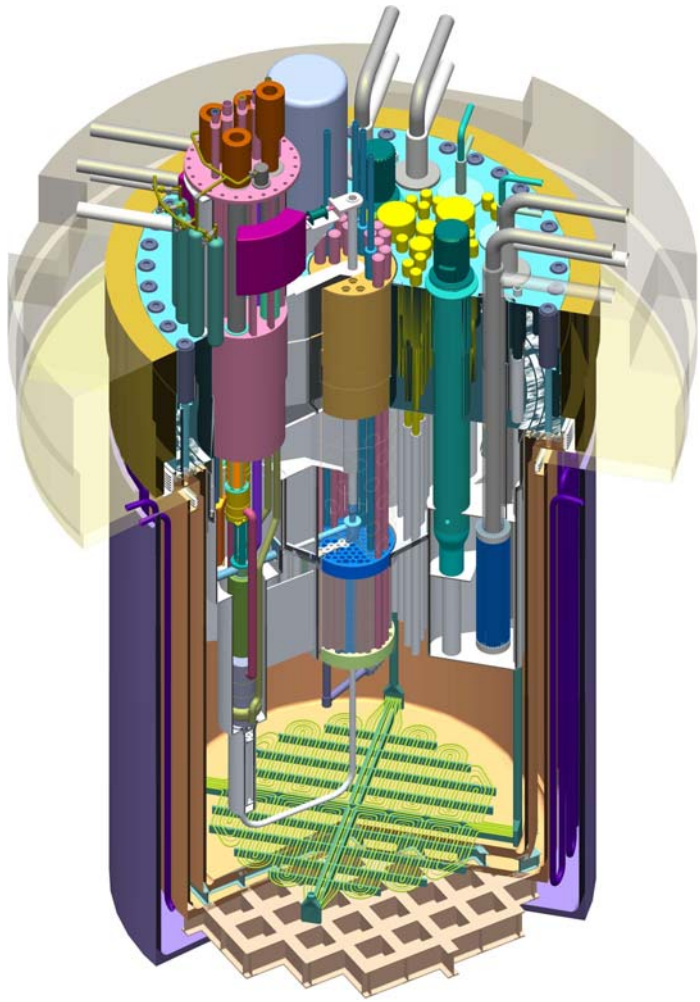
MYRRHA/XT-ADS
eXperimenTal-ADS: applications catalogue

MYRRHA

- ADS first step demonstration facility
  - Coupling of three components at reasonable power level (~50-100 MWth)
  - ADS Operational and Safety studies
    - ⇒Operation with liquid metal coolant (Lead-Bismuth Eutectic)
    - ⇒Operation feed-back with sub-criticality monitoring and control
    - ⇒Beam trip mitigation and restart procedures after interruptions
    - ⇒Spallation products monitoring and control
  - P&T testing facility



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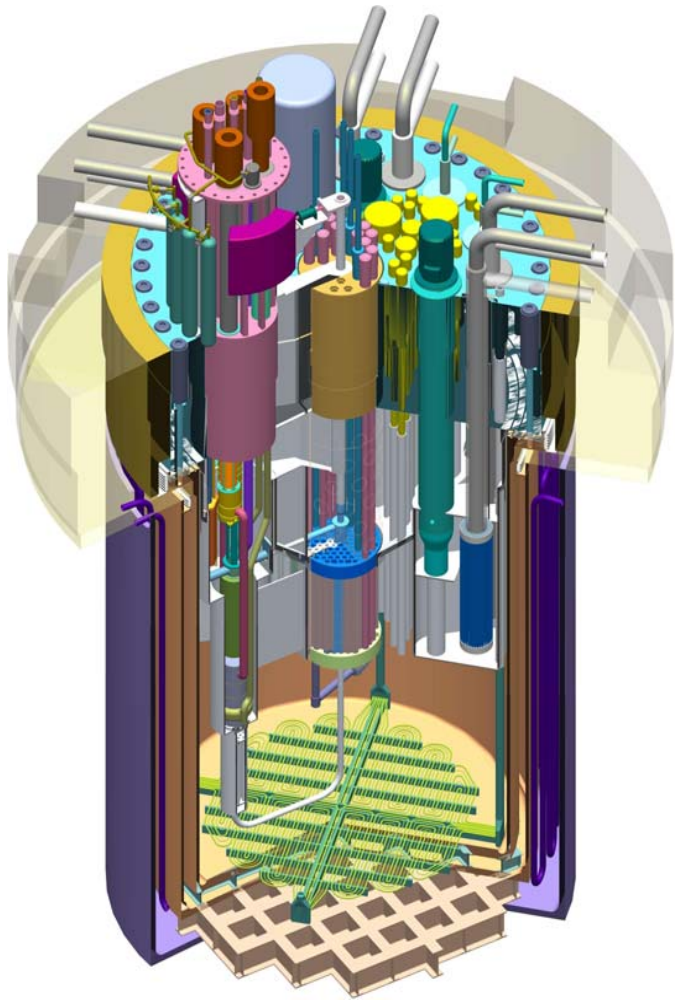
MYRRHA/XT-ADS
eXperimenTal-ADS: applications catalogue

MYRRHA

- Flexible irradiation facility in Europe
  - Fast spectrum : complementary to RJH (France)
  - GenIV applications
  - Materials research :PWR, BWR, Fusion, Fuel
  - Medical isotope production
  - Replacement of BR2 (100 MWth MTR at Mol)

Need for high performance core : high power density in limited volume

- $\Phi_{>0.75\ MeV}$ ~10^{15} n/cm^2 .s)
- Φ_{th} ~2.10^{15} n/cm^2 .s)



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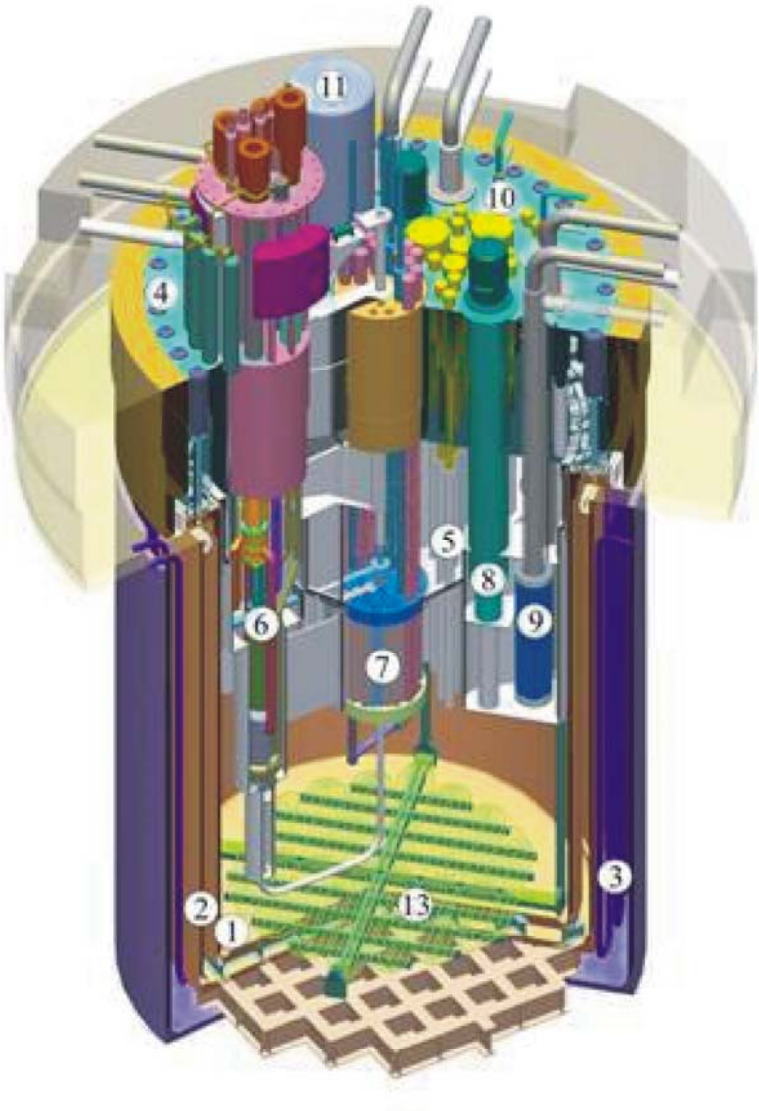
The MYRRHA machine



1. inner vessel
2. guard vessel
3. cooling tubes
4. cover
5. diaphragm
6. spallation loop
7. sub-critical core
8. primary pumps
9. primary heat exchanger
10. emergency heat exchanger
11. in-vessel fuel transfer machine
12. in-vessel fuel storage
13. coolant conditioning system

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Core configuration

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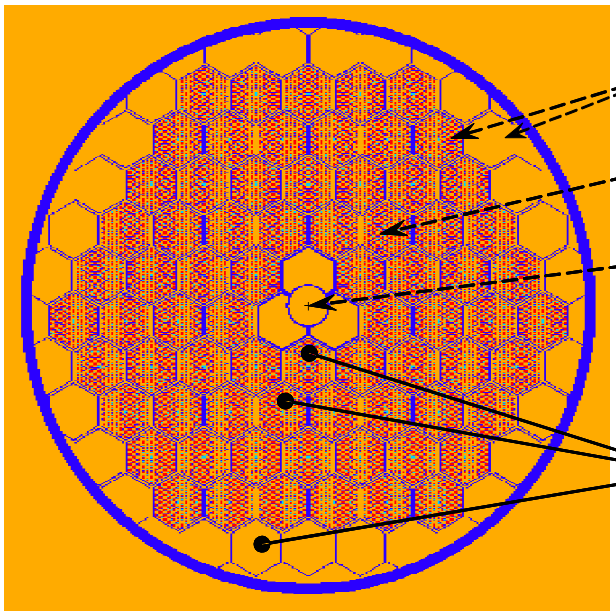
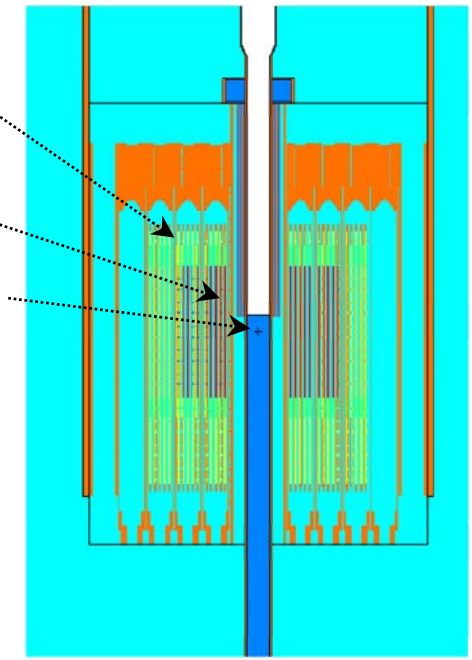
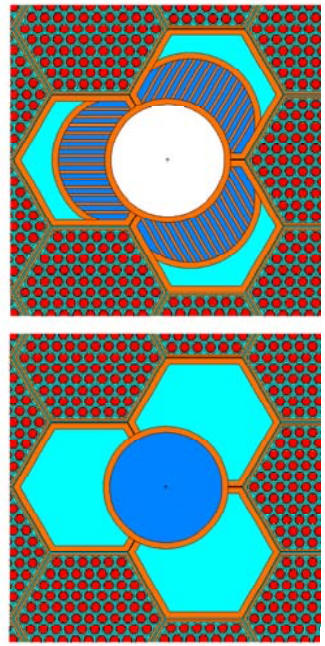
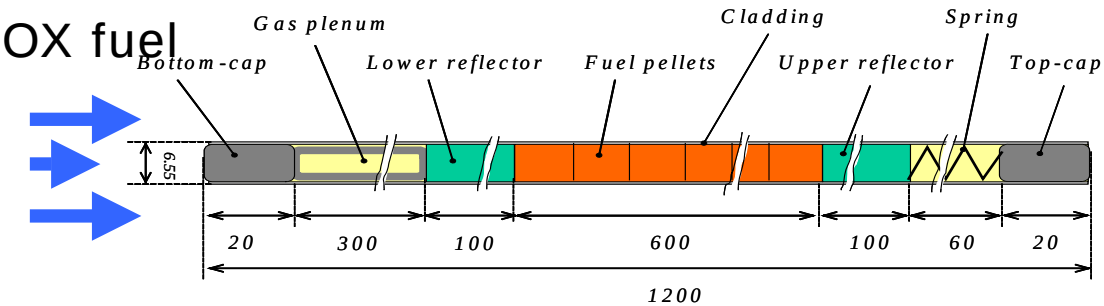






- hexagonal cells ("macro-cells")
- Target-block hole : 3 FA removed
- Surrounding active zone : MOX fuel
- Outer reflector zone



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Spallation target

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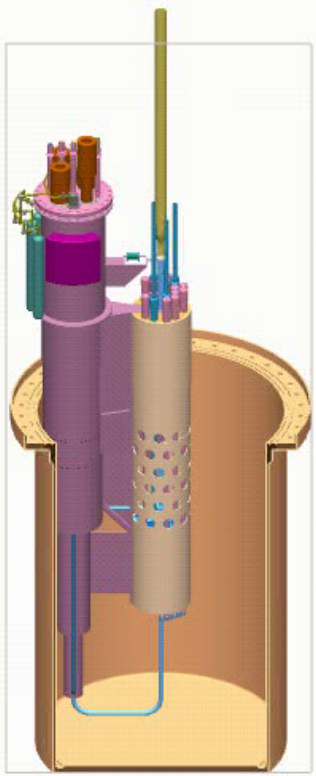


- Tasks
  - Produce 10^{17} neutrons/s to feed subcritical core @ k_{eff}=0.95
    - heavy target material
  - Accept megawatt proton beam
    - 600 MeV, 2.5-3 mA
    - liquid metal & forced convection
  - Fit into central hole in core
    - compact target
    - Off-axis geometry
  - Match MYRRHA purpose as experimental irradiation machine
    - flexible remote handling
  - Survive (lifetime)

Spallation target

- Windowless target
  - space considerations
  - beam density
- Formation of target free surface
  - Confluence of Vertical coaxial flow
  - Driving force : gravity
  - Level : balance inlet-outlet flow
  - Recirculation zone : in check
  - Feedback necessary
  - Proton beam distribution
    - ♣ Avoid recirculation zone heating

Maintenance, inspection and repair

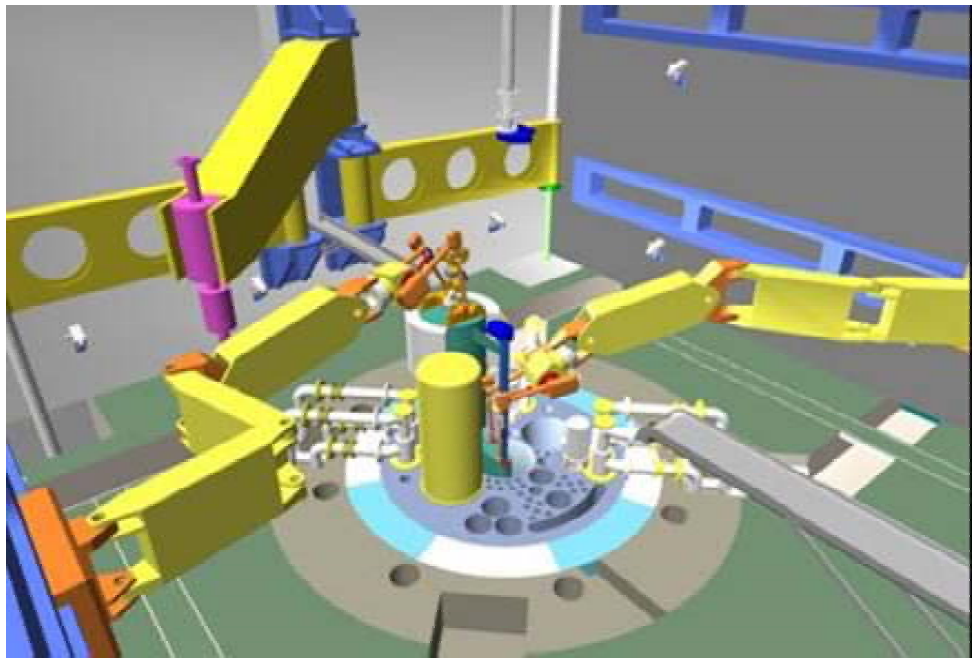
- Operation and maintenance of MYRRHA with remote handling systems
  - High activation on the top of the sub-critical reactor,
  - α-contamination due to ^{210}Po when extracting components from the reactor pool,
  - non-visibility under Pb-Bi,
- Develop appropriate “In Service Inspection and Repair” (ISIR) and ultrasonic (US) visualisation systems.
- Maintenance schedule

3 1 3 1 3 3

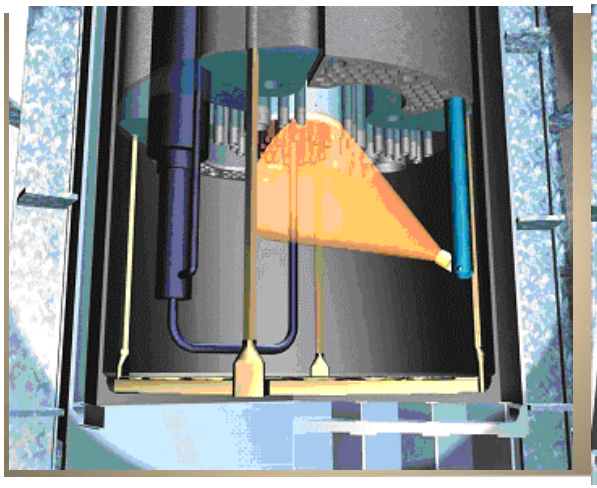
Remote handling

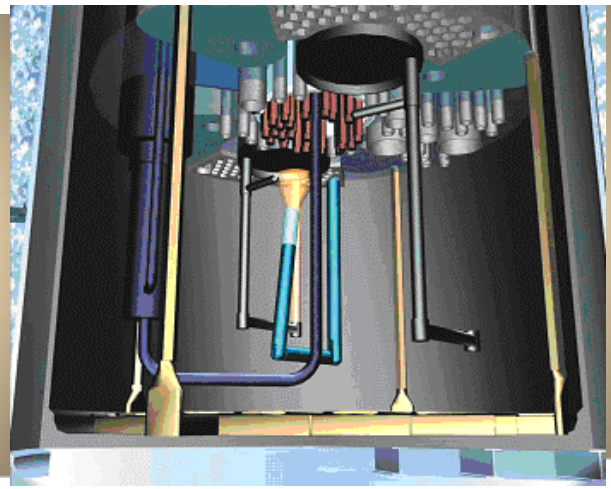
All MYRRHA maintenance operations on the machine primary systems and associated equipment are performed by remote handling, which is based on the *Man-In-The-Loop principle*:

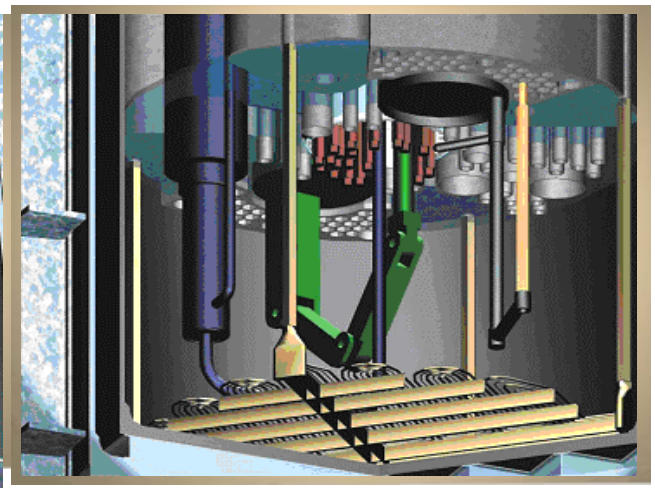
- force reflecting servomanipulators
- Master-Slave mode: the slave servo-manipulators are commanded by remote operators using kinematically identical master manipulators
- supported with closed-cycle TV (CCTV) feedback



In-service inspection and repair







Two permanently installed *inspection* manipulators with US camera to provide a general *overview*. (periscope type device with three degrees of freedom)

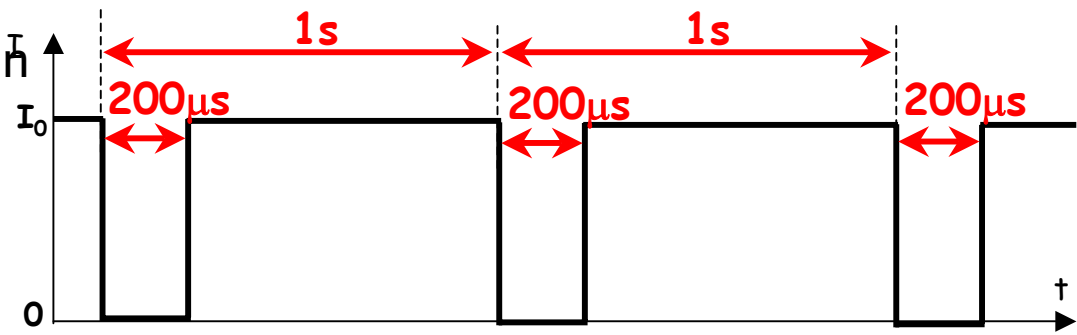
The second *inspection* manipulator positions the camera close to critical components for *detailed* inspection. (anthropomorphic type device with five degrees of freedom)

The *repair* manipulator recovers debris or deploys specialised tooling for repair. (anthropomorphic type device with eight degrees of freedom)

ADS Accelerator : Requirements

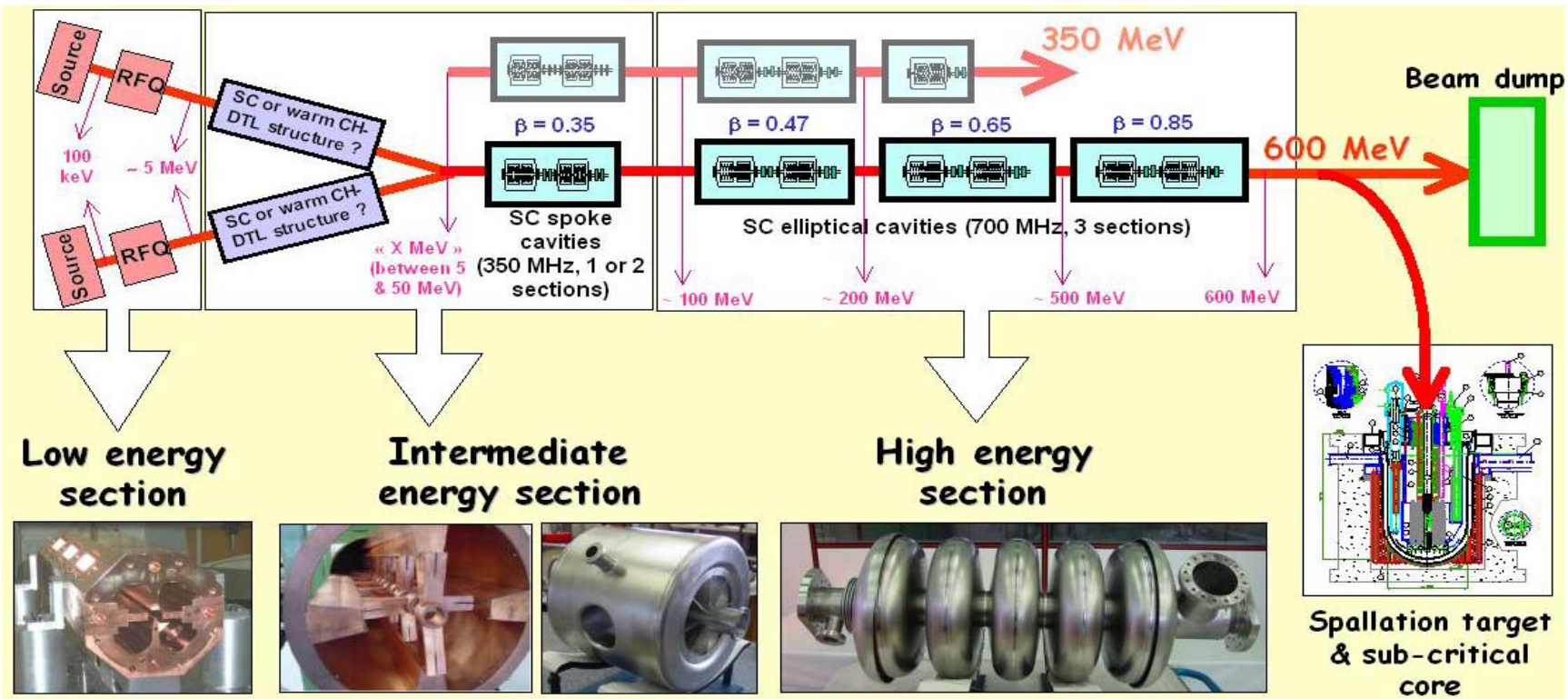
Proton Beam Specifications:

- 600 MeV*3 mA max for operation of XT-ADS
- High reliability :
  - **Less than 5 beam Trips > 1sec per cycle**
  - Power stability ±2%
  - Energy stability ±1%
  - Intensity stability ±2%
  - Beam footprint dimensions ±10%
- Additional requirements:
  - 200µs beam holes for on-line sub-criticality level measurement
  - Safety grade shut down



The choice of the Generic Accelerator Type

- LINAC
  - no limitation in energy & intensity
  - highly modular & upgradable
  - excellent potential for reliability : over-design, redundancy and fault tolerance
  - high efficiency (optimised operation cost)



Roadmap for ADS deployment

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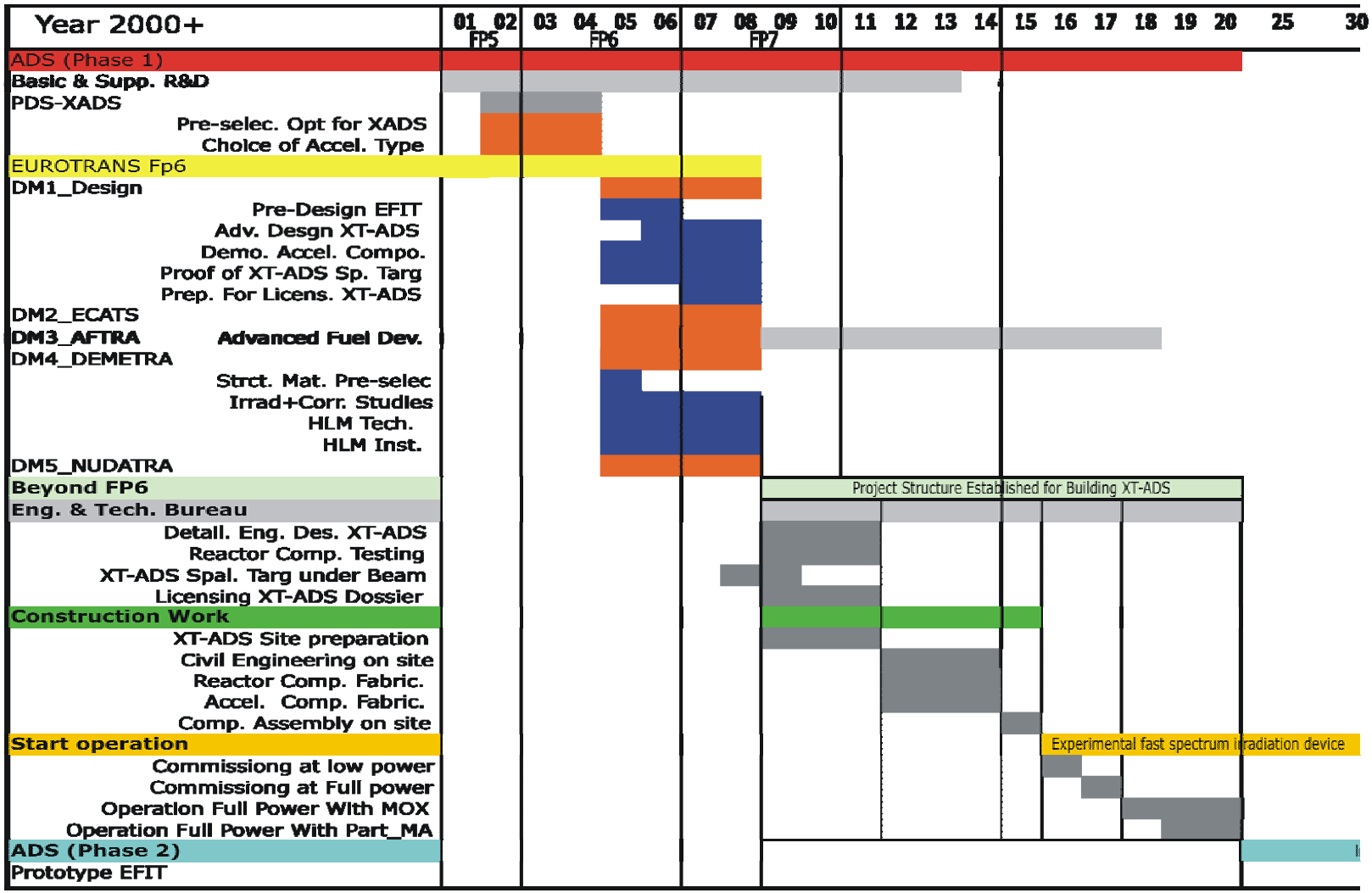
Schedule for ADS Deployment



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One picture is better than a thousand words, we are in 2016

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Imagine…

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- All the time : 10-100 µA 600 MeV protons
  - RF beam splitter
- Periodically : 2.5-3 mA 600 MeV protons
  - full beam
- Proton beam applications
  - Materials testing, Medical isotope production, Proton therapy
- Nuclear Physics
  - In-beam experiments ?
  - Isotope production ?
    - ♣ Energy boosting to 1 GeV ?
  - Spallation source ?
- Implementation in design : MYRRHA-team
- Physics case building : Nuclear physics community
  - workshop within IAP frame